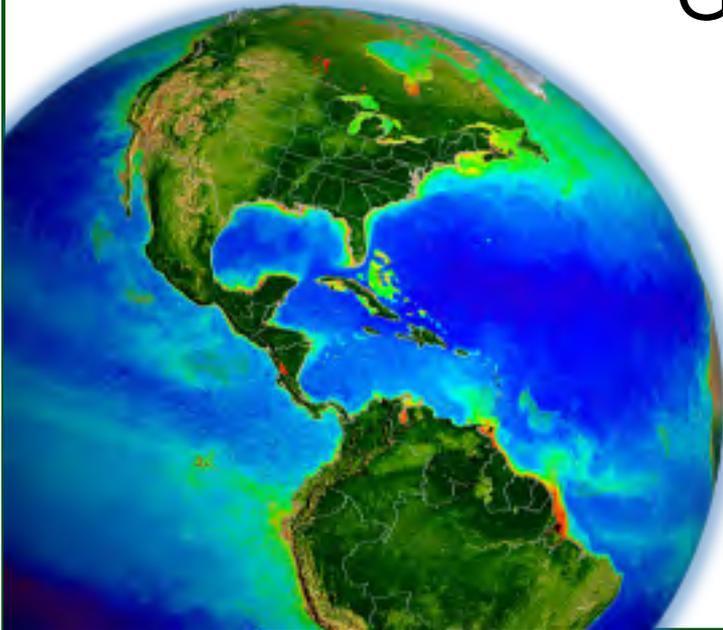


SNPP VIIRS

On-Orbit Calibration for Ocean Color Applications

Gene Eplee, Kevin Turpie,
Gerhard Meister, and Fred Patt

NASA Ocean Biology
Processing Group



MODIS / VIIRS Science Team Meeting
May 2015

OBPG VIIRS On-Orbit Calibration Methodology

On-orbit calibration of the Suomi National Polar-Orbiting Partnership Visible Infrared Imaging Radiometer Suite for ocean color applications

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The NASA Ocean Biology Processing Group (OBPG) developed two independent calibrations of the Suomi National Polar-Orbiting Partnership (SNPP) Visible Infrared Imaging Radiometer Suite (VIIRS) moderate resolution reflective solar bands using solar diffuser measurements and lunar observations, and implemented a combined solar- and lunar-based calibration to track temporal changes in radiometric response of the instrument. Differences between the solar and lunar data sets have been used to identify issues and verify improvements in each. Linearization of the counts-to-radiance conversion yields a more consistent calibration at low radiance levels. Correction of a recently identified error in the VIIRS solar unit vector coordinate frame has been incorporated into the solar data and diffuse screen transmission functions. Temporal trends in the solar diffuser stability monitor data have been evaluated and addressed. Fits to the solar calibration time series show mean residuals per band of 0.067%–0.17%. Periodic residuals in the VIIRS lunar data are confirmed to arise from a wavelength-dependent libration effect for the sub-spacecraft point in the output of the U.S. Geological Survey Robotic Lunar Observatory photometric model of the Moon. Temporal variations in the relative spectral responses for each band have been assessed, and significant impact on band M1 (412 nm) lunar data has been identified and rectified. Fits to the lunar calibration time series, incorporating sub-spacecraft point libration corrections, show mean residuals per band of 0.069%–0.20%. Lunar calibrations have been used to adjust the solar-derived radiometric corrections for bands M1, M3, and M4. After all corrections, the relative differences in the solar and lunar calibrations for bands M1–M7 are 0.093%–0.22%. The OBPG has achieved a radiometric stability for the VIIRS on-orbit calibration that is commensurate with those achieved for SeaWiFS and Aqua MODIS, supporting the incorporation of VIIRS data into the long-term NASA ocean color data record. © 2015 Optical Society of America

OCIS codes: (280.0280) Remote sensing and sensors; (280.4788) Optical sensing and sensors; (280.4991) Passive remote sensing; (010.1690) Color; (010.5630) Radiometry; (120.0280) Remote sensing and sensors.

<http://dx.doi.org/10.1364/AO.54.001984>

1559-128X/15/081984-23\$15.00/0
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1984 APPLIED OPTICS / Vol. 54, No. 8 / 10 March 2015

1. Introduction

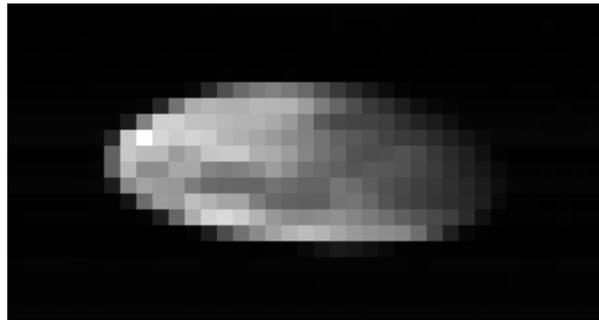
The Suomi National Polar-Orbiting Partnership (SNPP) Visible Infrared Imaging Radiometer Suite (VIIRS) was launched into an 824 km sun-synchronous

Applied Optics 54, 1984-2006 (2015)

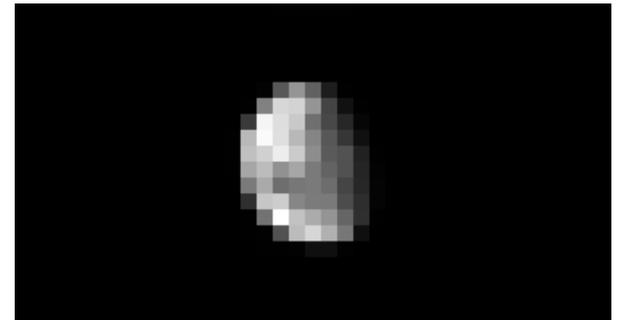
OBPG On-Orbit Calibration Updates

- An additional year of solar/lunar observations (Jan 2012–May 2015).
- Empirical libration angle corrections extended to sub-solar point:
 - Scatter in lunar data small enough for residual sub-solar libration effects to be observed in addition to sub-spacecraft libration effects.
 - Corrections result in a further reduction of scatter in lunar observations.
- First substantive derivation of SWIR band calibration:
 - Sun Pointing Anomaly in March 2012.
 - Residual libration effects also observed in SWIR band lunar data.
- Absolute calibration of solar observations using diffuser measurements:
 - Vicarious calibration will mitigate gain adjustments for bands M1-M6.
 - 2% gain adjustment for band M7.
 - Absolute calibration sets response for SWIR band solar time series.

Lunar Calibrations



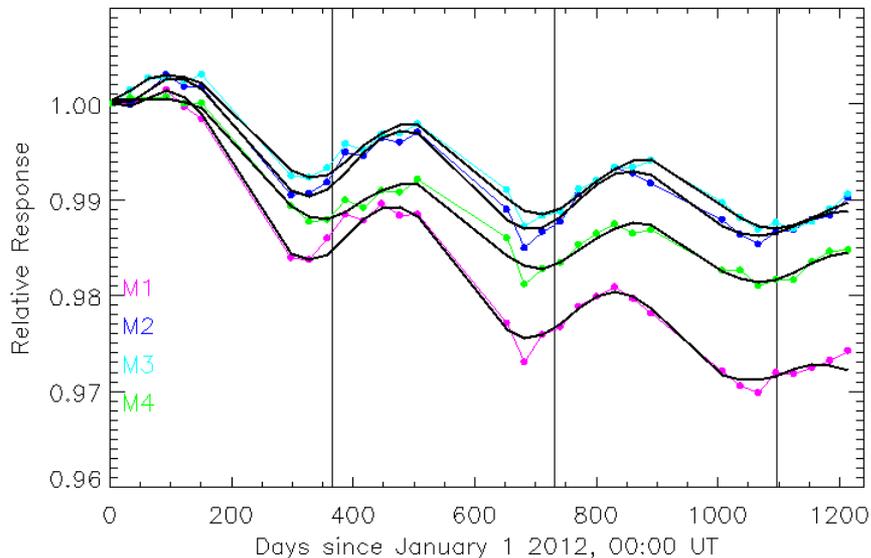
Band 4
Unaggregated



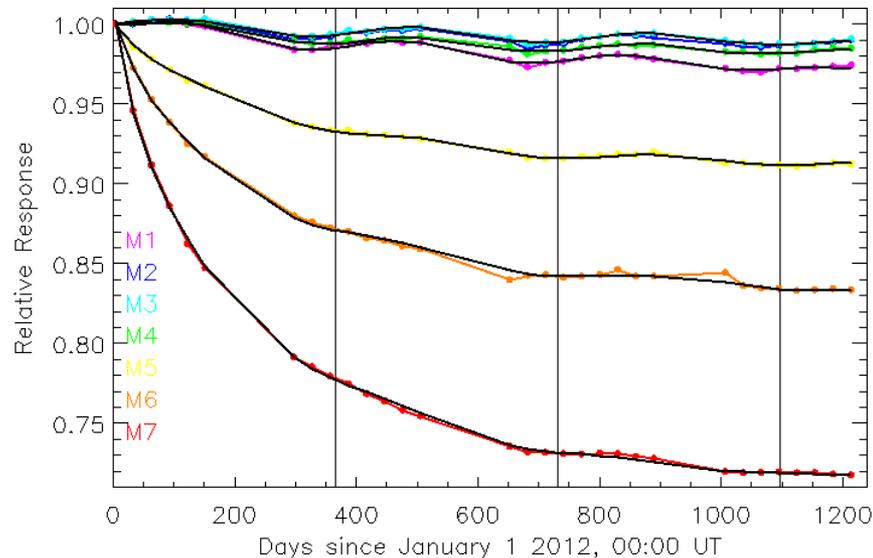
Band 6
Aggregated

Lunar Calibration Time Series

VIIRS VisNir Lunar Calibrations



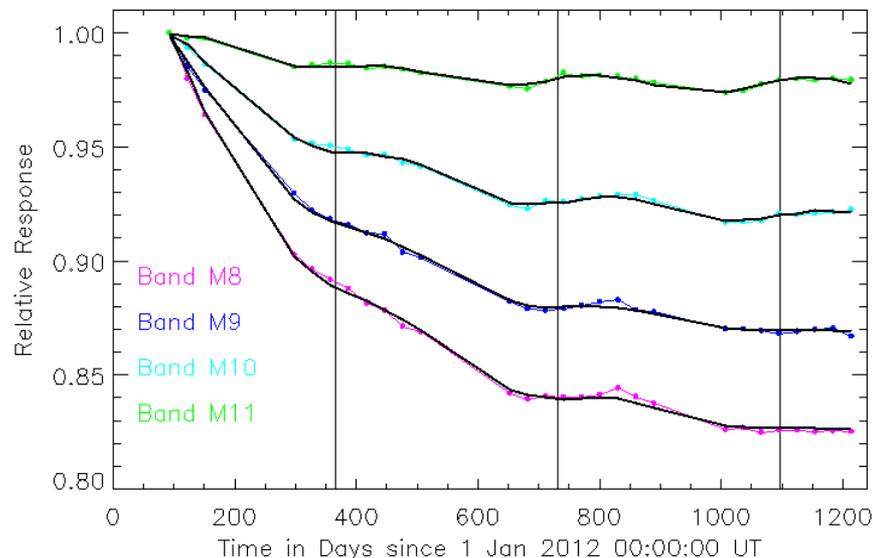
VIIRS VisNir Lunar Calibrations



Lunar time series are ratios of VIIRS observations to USGS ROLO model predictions made using modulated VIIRS spectral response functions.

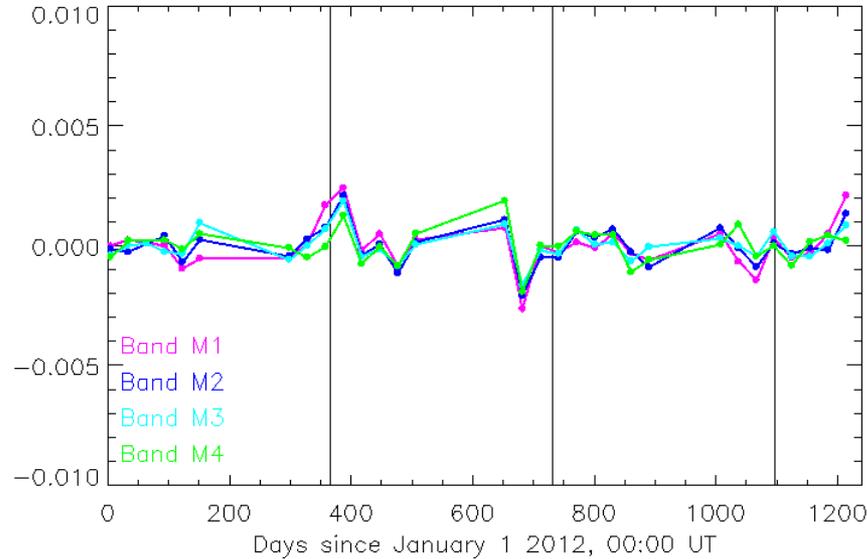
Fits are exponentials of time plus linear functions of sub-spacecraft and sub-solar libration angles.

VIIRS Lunar Calibration Time Series

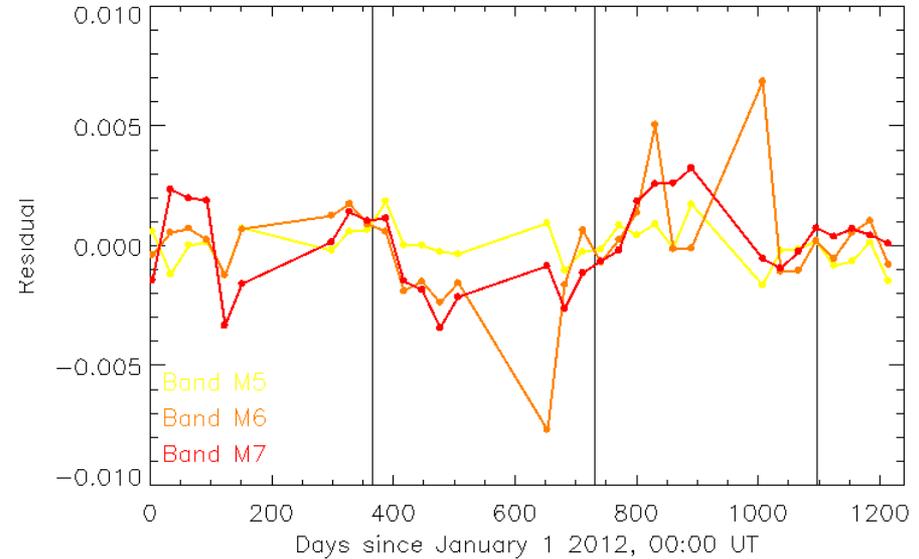


Lunar Calibration Fit Residuals

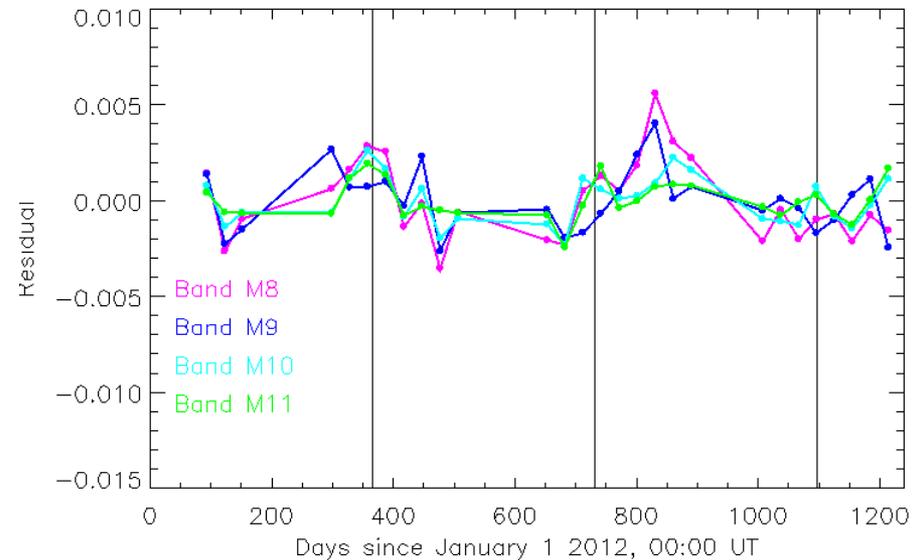
VIIRS VisNir Lunar Calibrations



VIIRS VisNir Lunar Calibrations

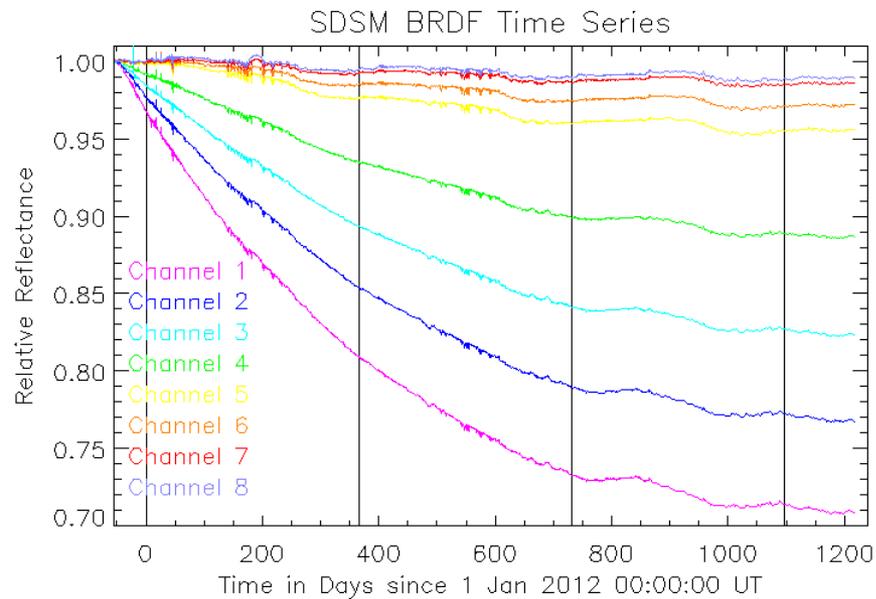


VIIRS SWIR Lunar Calibrations



The sub-spacecraft and sub-solar libration corrections capture the periodic signals in the lunar time series.

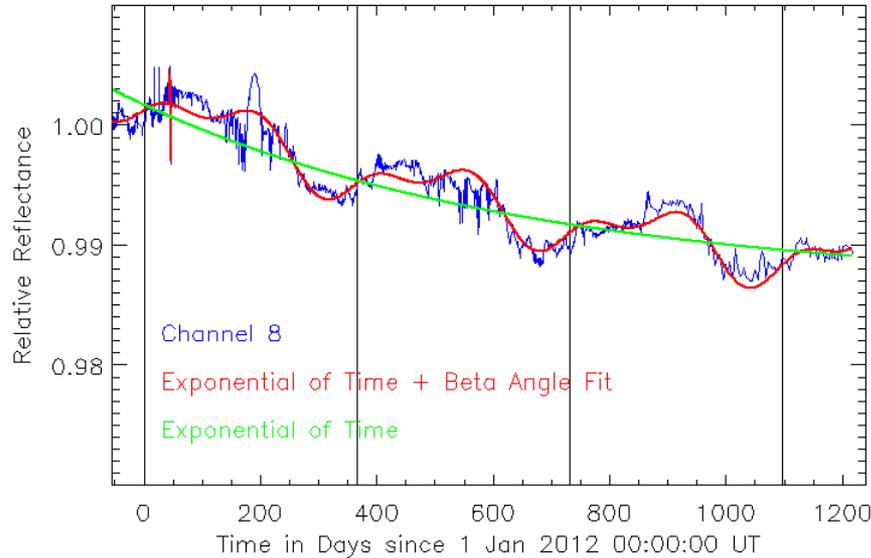
SDSM Calibrations



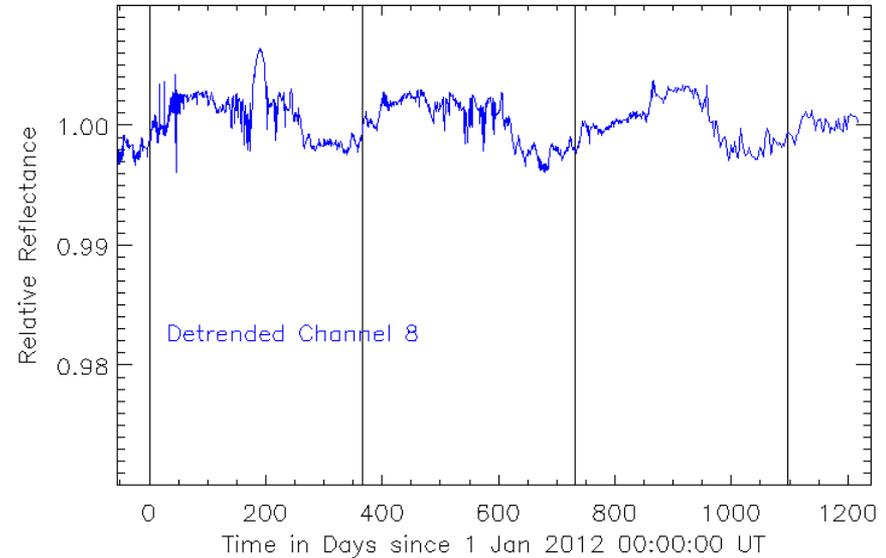
Channels 1-7 correspond to bands M1-M7.
Channel 8 (935 nm) tracks SDSM performance.

SDSM Calibration Time Series

SDSM Channel 8 BRDF Time Series



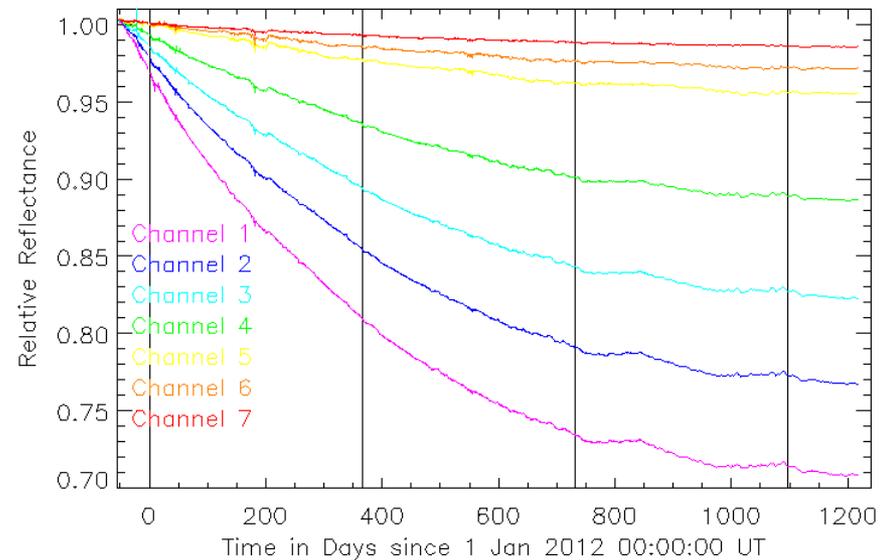
SDSM Channel 8 BRDF Time Series



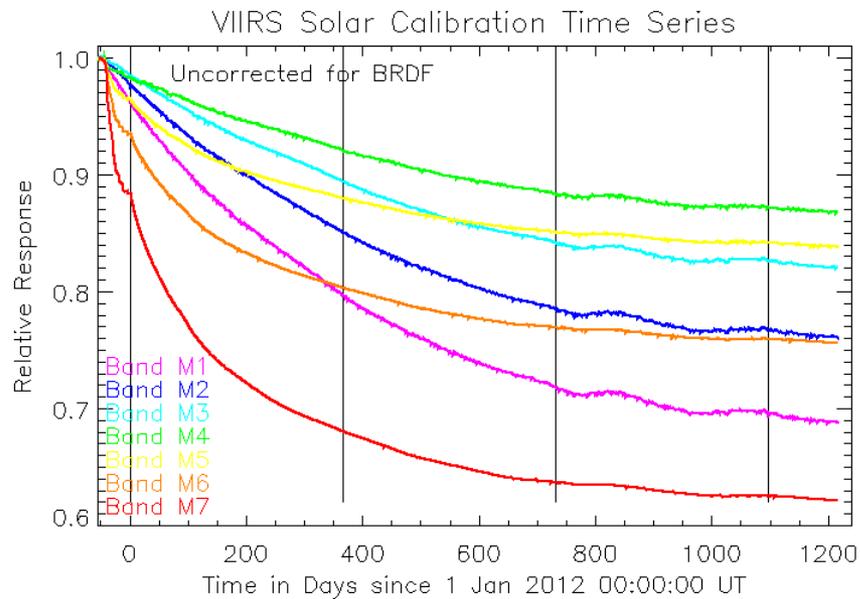
SDSM channel 8 is fit with an exponential function of time plus a linear function of solar beta angle.

Normalization of channels 1-7 by detrended channel 8 reduces noise and beta angle dependence without changing temporal dependence.

SDSM Normalized BRDF Time Series



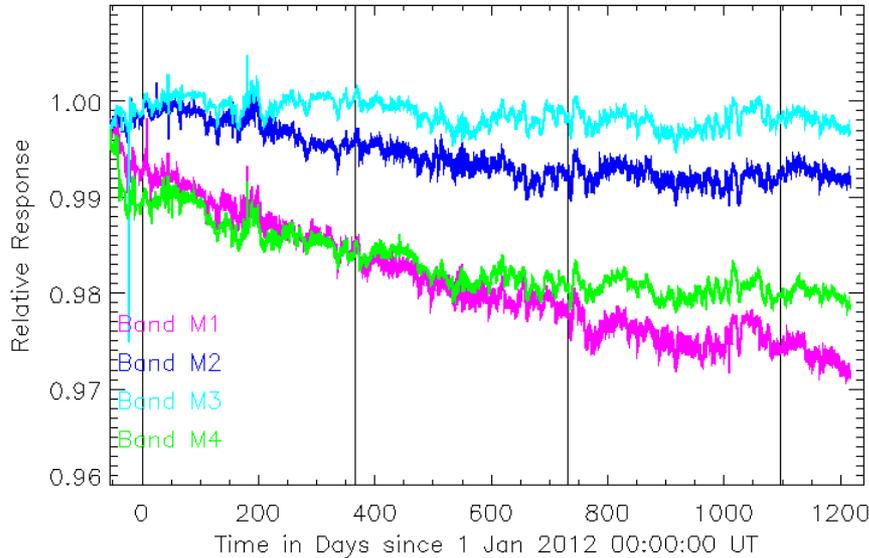
Solar Calibrations



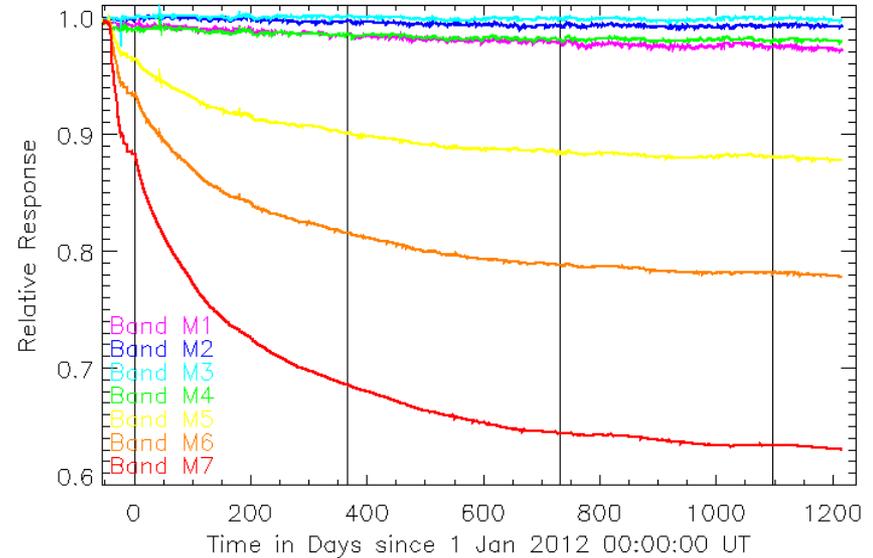
Solar calibration time series for band M1-M7, uncorrected for diffuser BRDF degradation.

Solar Calibration Time Series

VIIRS Solar Calibration Time Series



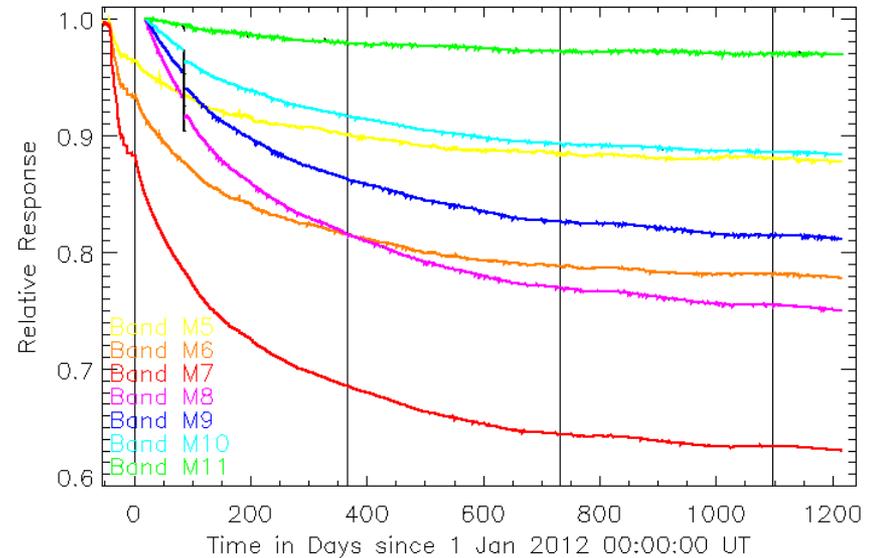
VIIRS Solar Calibration Time Series



Bands M1-M7 are corrected for diffuser BRDF degradation by SDSM-derived H-factors.

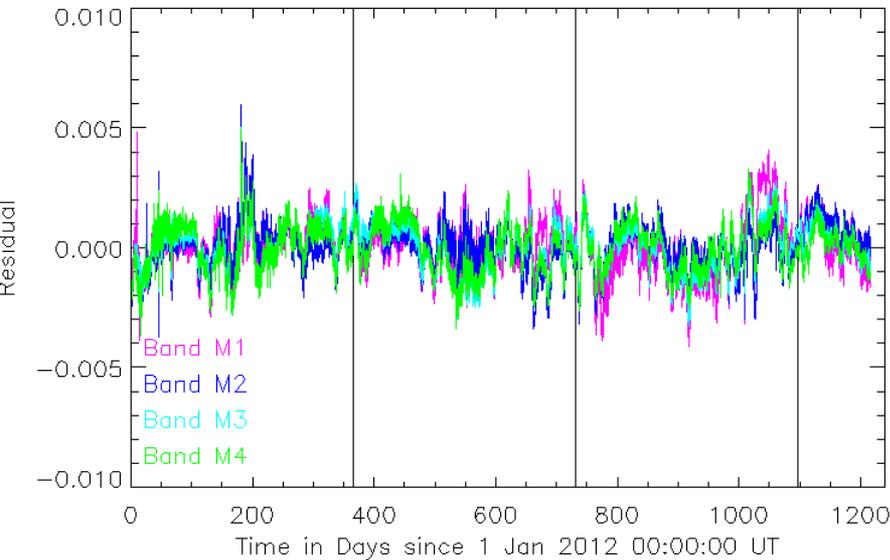
SWIR band radiometric responses changed discontinuously during March 2012 Sun Pointing Anomaly.

VIIRS Solar Calibration Time Series

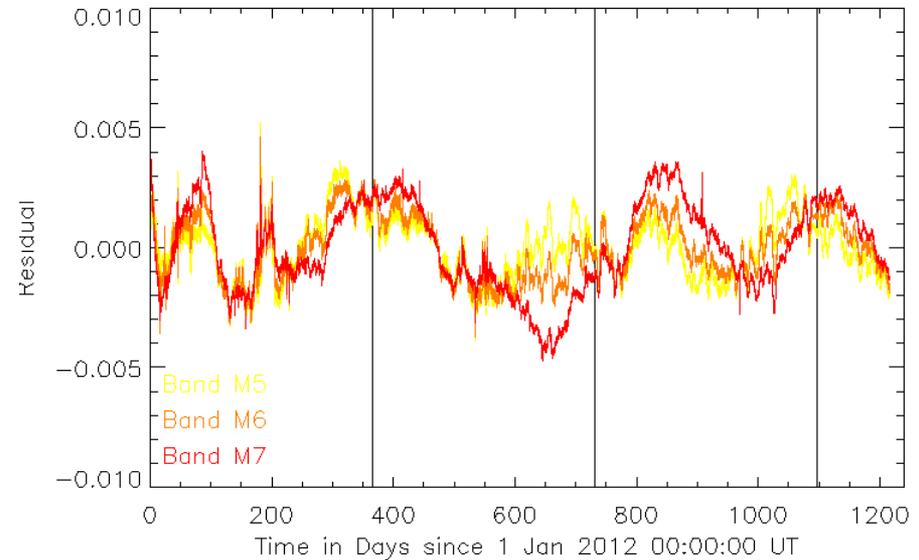


Solar Calibration Fit Residuals

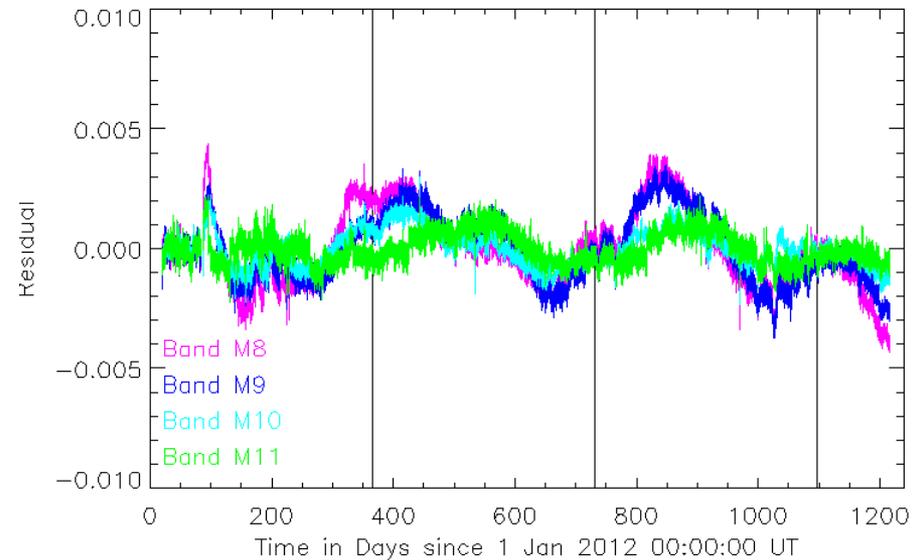
VIIRS Solar Calibration Time Series



VIIRS Solar Calibration Time Series



VIIRS Solar Calibration Time Series



The detrended SDSM channel 8 normalization and the latest screen transmission / diffuser BRDF functions derived by VCST minimize periodic signals in the solar time series.



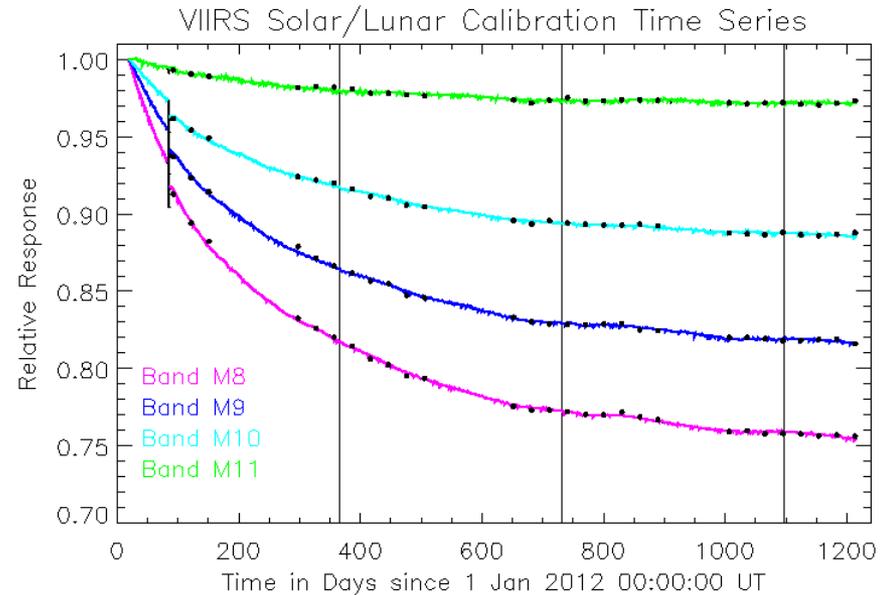
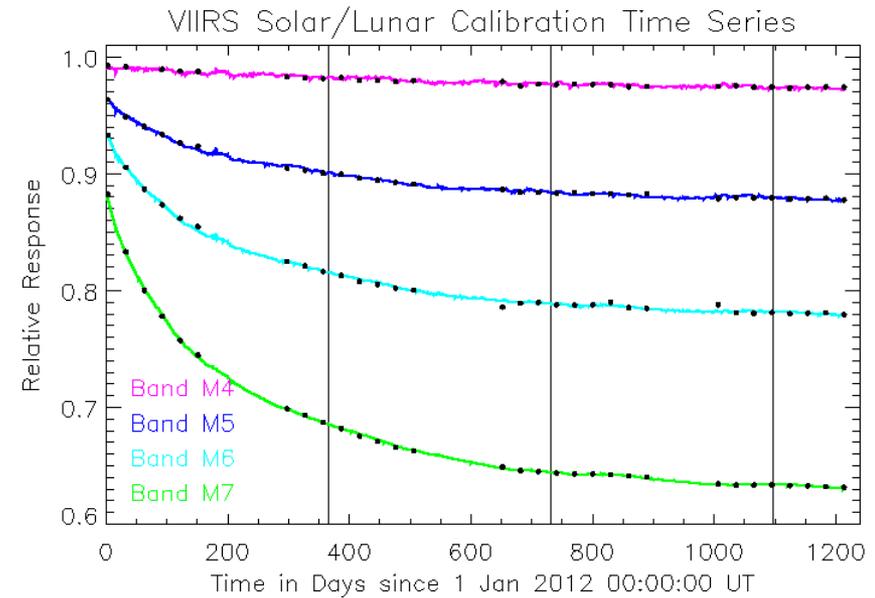
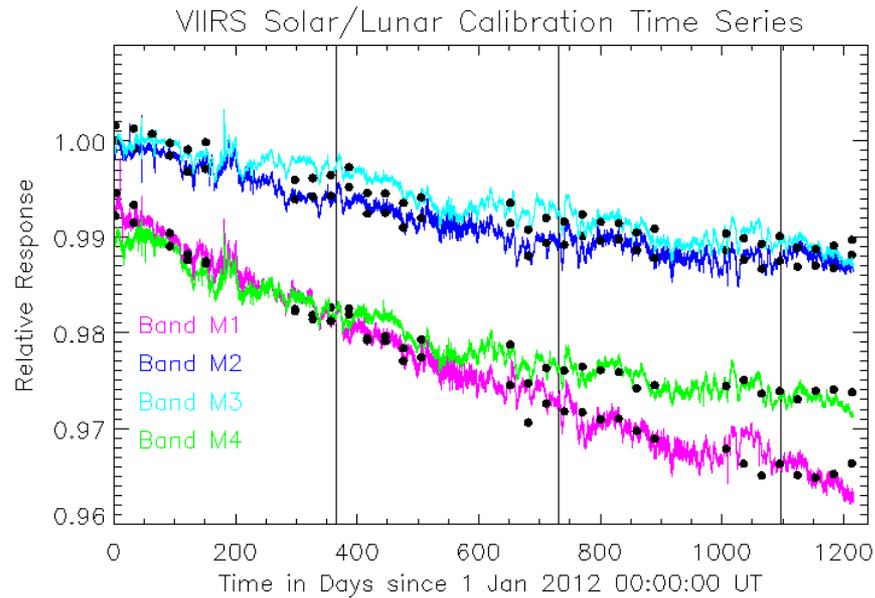
Solar / Lunar Calibration Comparisons

Concern over how effectively
SDSM observations track
solar diffuser BRDF degradation.

VIIRS observes the solar diffuser and
the space view (Moon)
at the same angle of incidence (60.2°)
on the half-angle mirror.

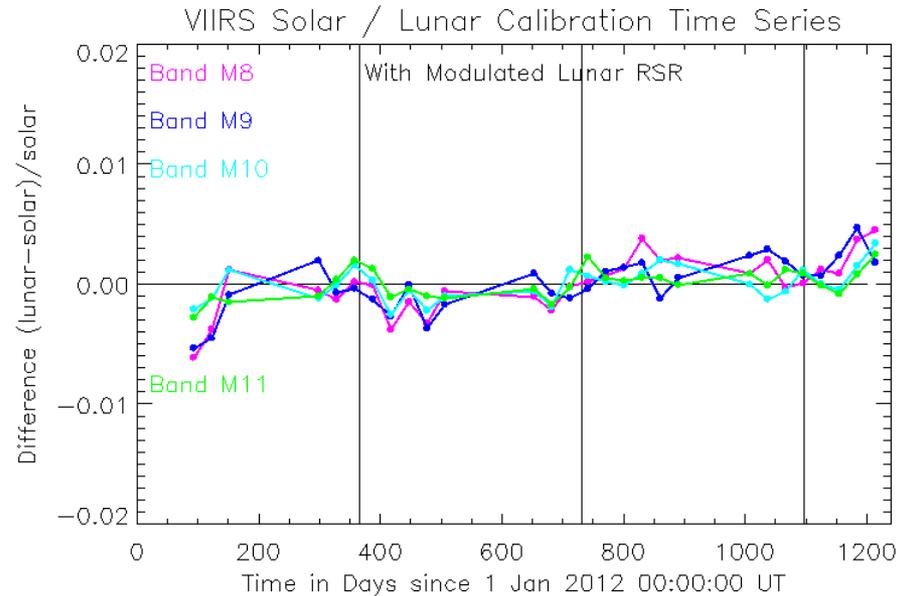
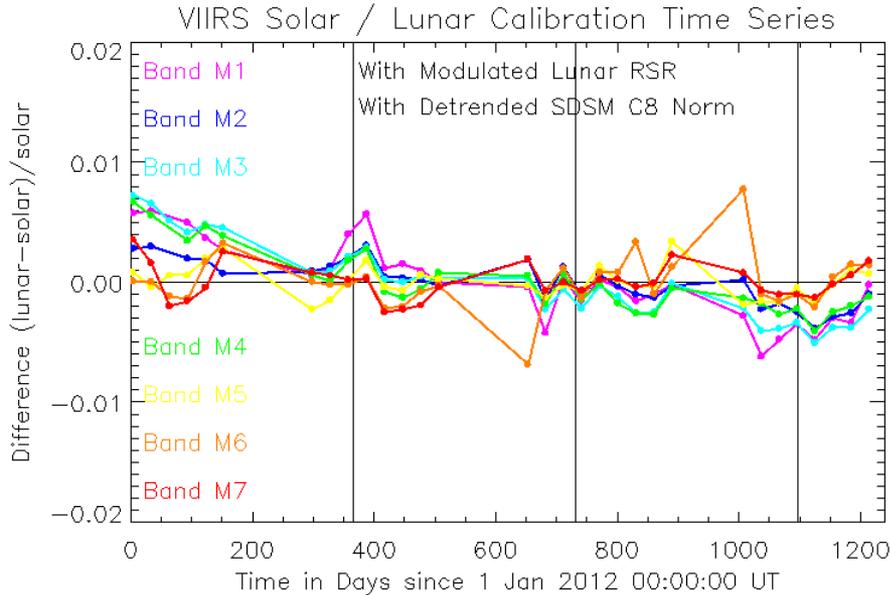


Solar / Lunar Calibration Comparisons



Single normalizations are applied to each band of the lunar time series to account for calibration biases.

Initial Solar / Lunar Calibration Comparisons



Point-by-point calibration comparisons are made using closest solar observation to each lunar observation.

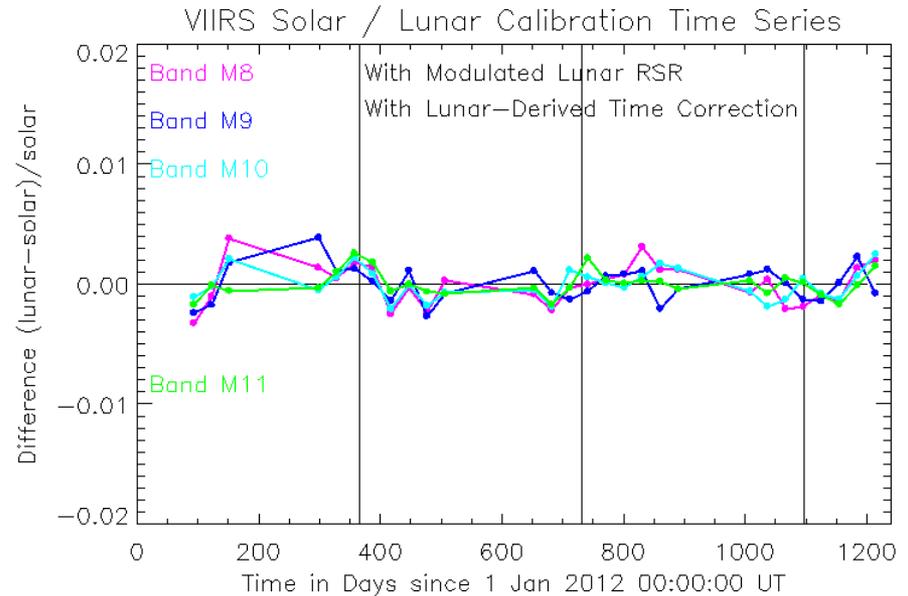
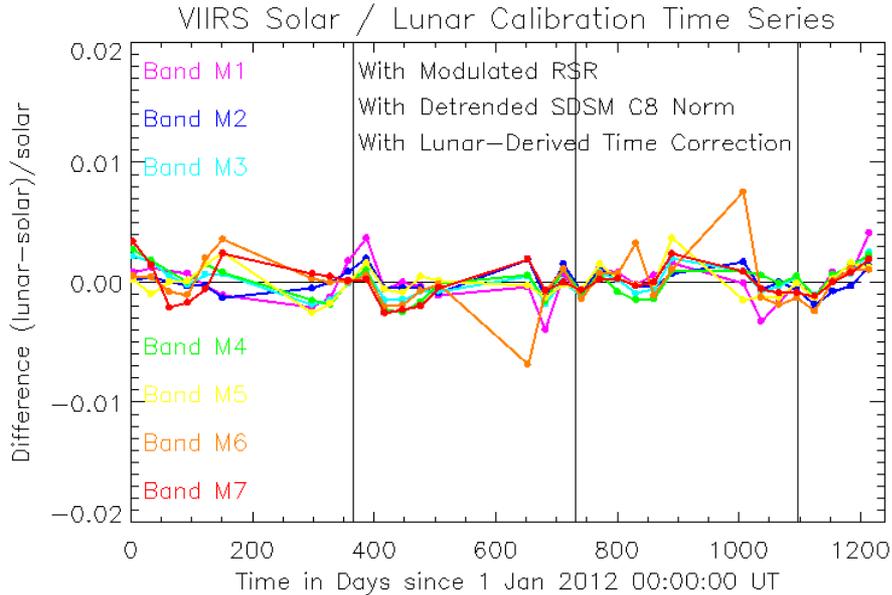
Slopes of the comparisons provide lunar-derived adjustments for the solar calibration time series.

Solar / Lunar Calibration Comparisons

Band	λ (nm)	Initial Slope	Revised Slope
M1	412	-7.578E-06	4.012E-08
M2	445	-4.138E-06	1.0644E-08
M3	488	-8.048E-06	4.0553E-08
M4	555	-6.115E-06	2.898E-08
M5	672	-9.108E-07	6.347E-10
M6	746	6.485E-07	4.370E-11
M7	865	-2.767E-07	1.325E-10
M8	1240	4.836E-06	1.633E-08
M9	1378	4.900E-06	1.672E-08
M10	1610	1.740E-06	1.880E-09
M11	2250	1.805E-06	2.506E-09

Units for the slopes are fractional change per day.

Final Solar / Lunar Calibration Comparisons



Comparisons with the lunar-derived adjustments applied to the solar calibration time series.

Lunar time series provides long-term stability reference for each band while solar time series provides per-detector, per-gain calibration.

Final Solar / Lunar Calibration Comparisons

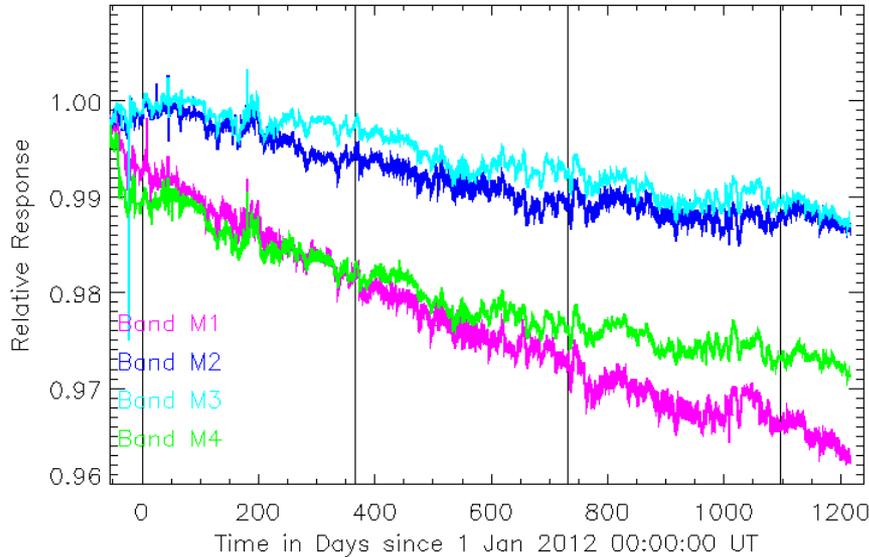
Band	Solar Residuals	Lunar Residuals	Solar / Lunar Differences
M1	0.115	0.0955	0.166
M2	0.0941	0.0788	0.0973
M3	0.103	0.0645	0.116
M4	0.0989	0.0719	0.136
M5	0.130	0.0830	0.129
M6	0.131	0.230	0.230
M7	0.182	0.175	0.142
M8	0.160	0.208	0.170
M9	0.137	0.161	0.150
M10	0.0745	0.127	0.127
M11	0.0661	0.0988	0.105

RMS residuals and RMS differences are in percent.

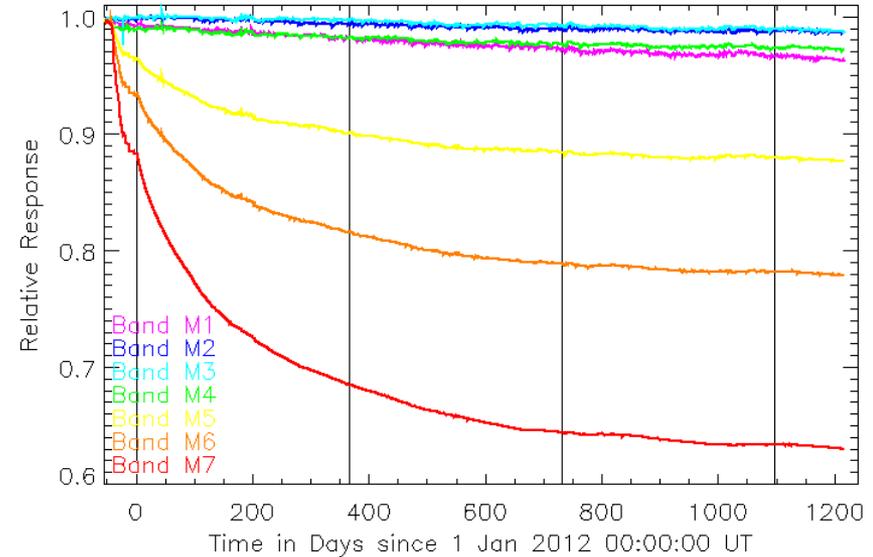
VIIRS calibration stability is comparable to that achieved for heritage instruments (SeaWiFS, Aqua MODIS).

Lunar-Adjusted Solar Calibration Time Series

VIIRS Solar Calibration Time Series

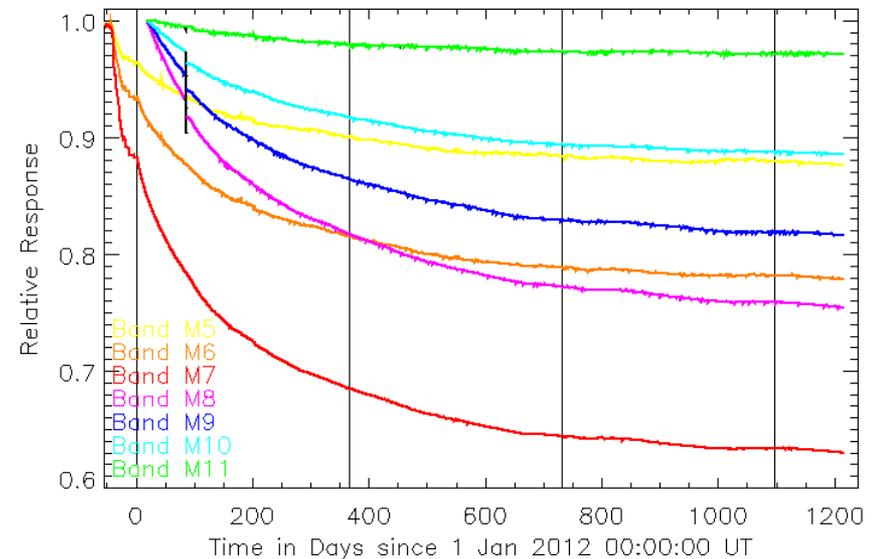


VIIRS Solar Calibration Time Series



Vicarious calibration is applied to bands M1-M6.

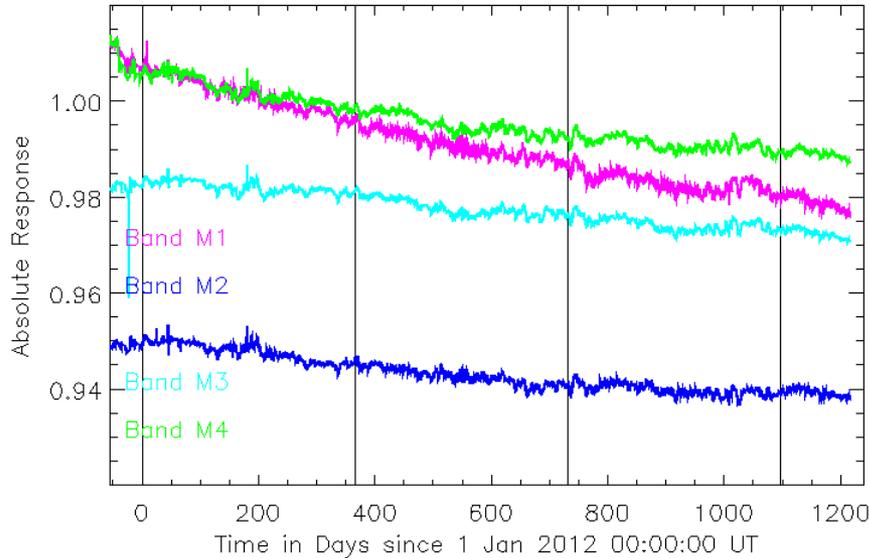
VIIRS Solar Calibration Time Series



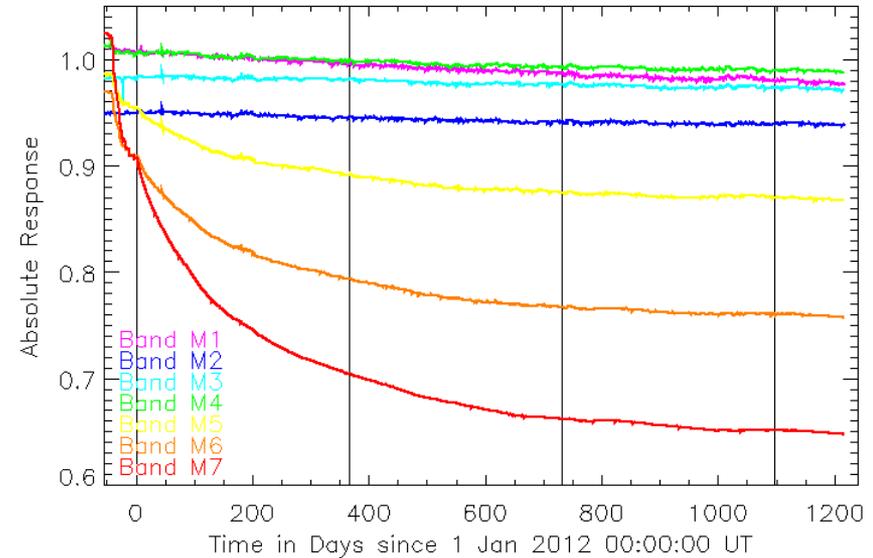
Fits to lunar-adjusted solar calibration time series for bands M1-M7 provided the calibration used for Reprocessing 2014.0.

Absolute Solar Calibration Time Series

VIIRS Solar Calibration Time Series



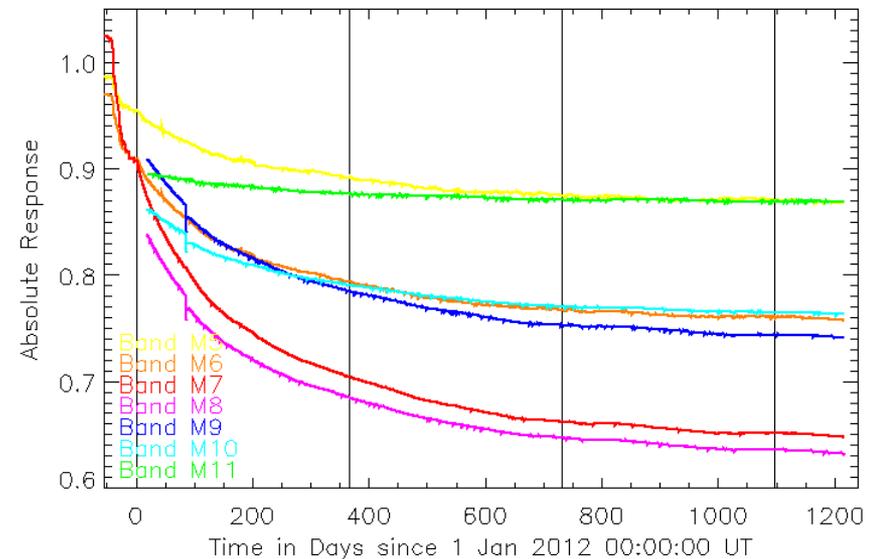
VIIRS Solar Calibration Time Series



Responses for bands M8-M11 are consistent with NIR Degradation Anomaly.

Fits to lunar-adjusted SWIR band solar calibration time series are under evaluation by OBPG for alternate atmospheric correction.

VIIRS Solar Calibration Time Series



Calibration Validation: Ocean Color Data Reprocessing 2014.0



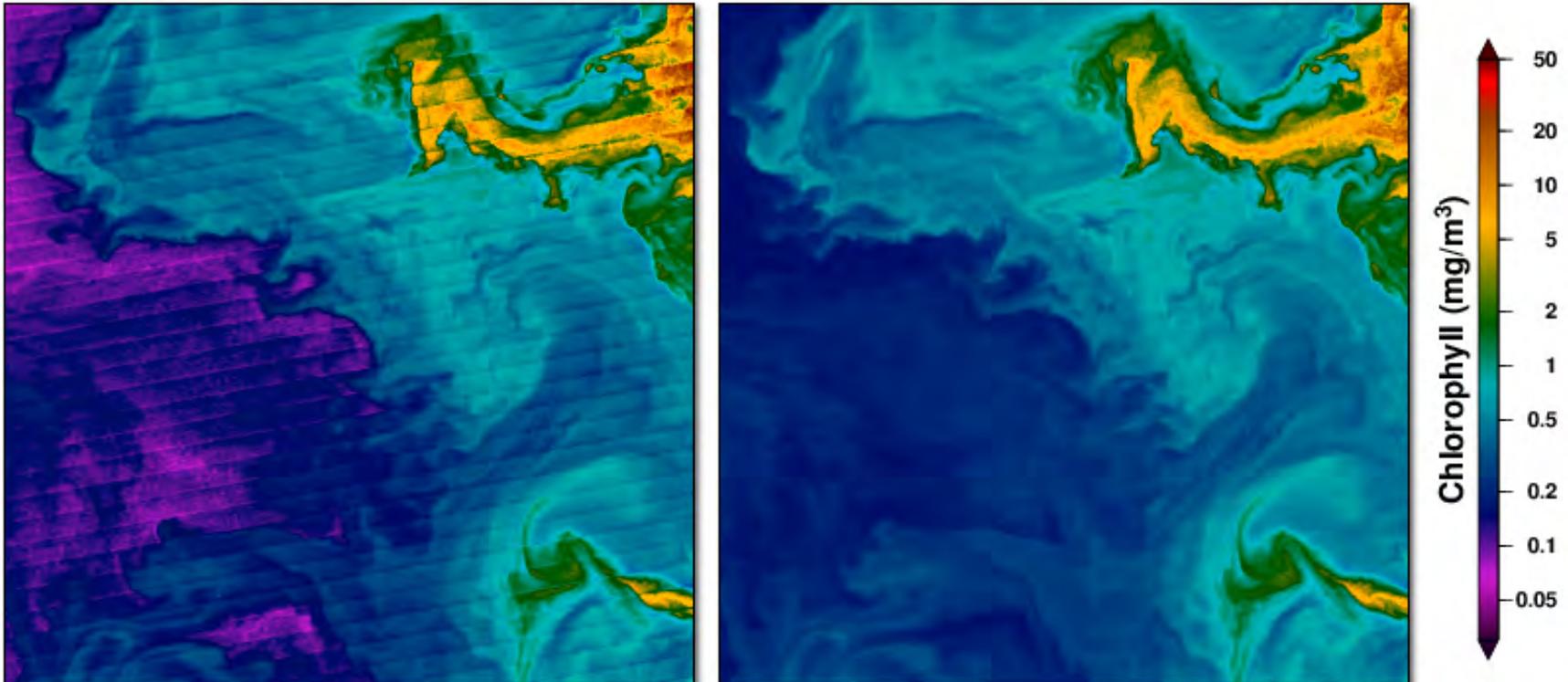
Earth Day 2015

Image courtesy of
Norman Kuring,
NASA OBPG

Improved Calibration Yields Improved Chlorophyll Retrievals

Reprocessing 2013.1

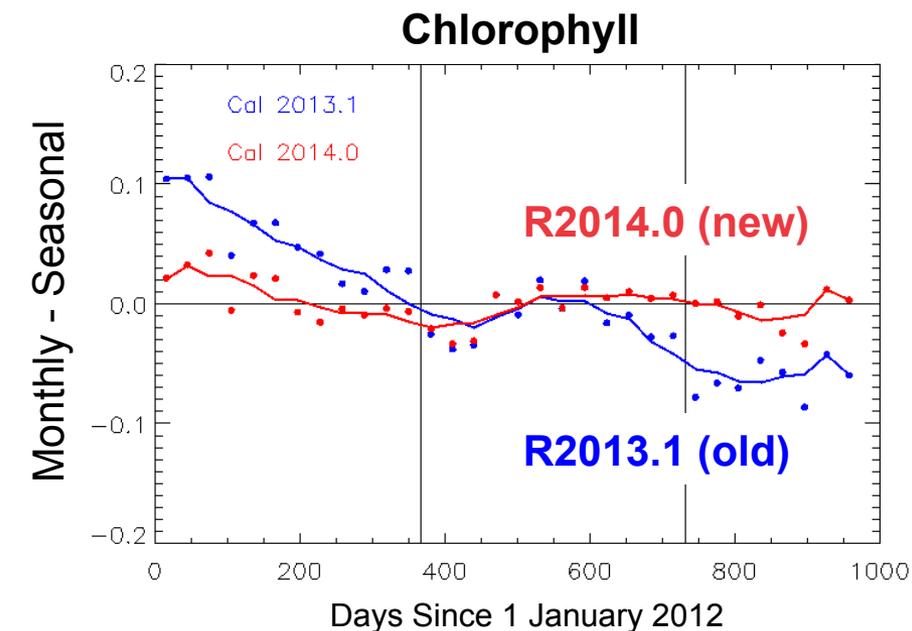
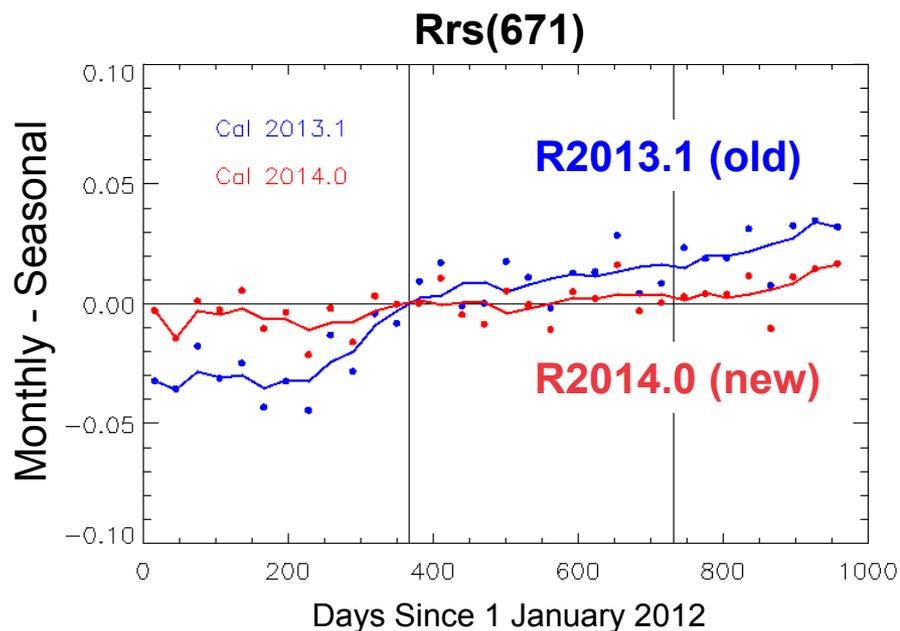
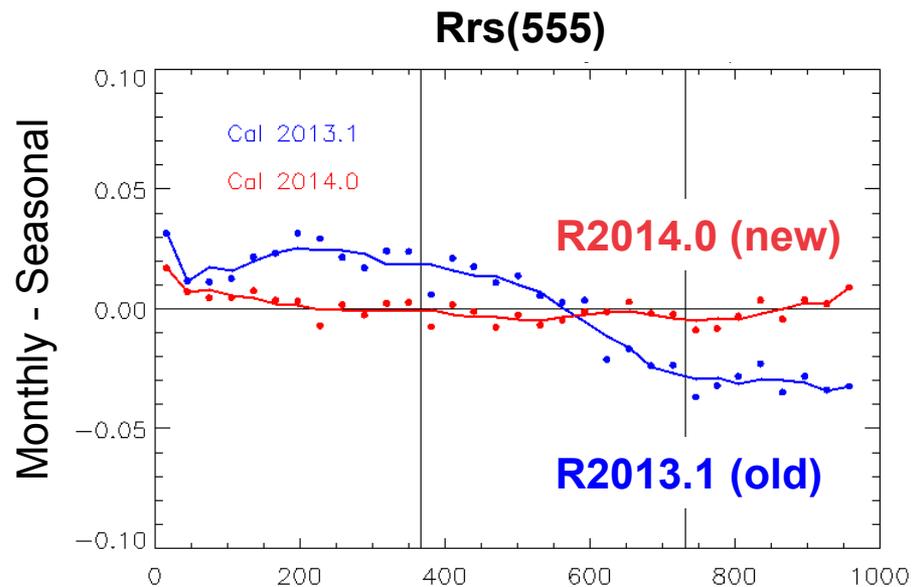
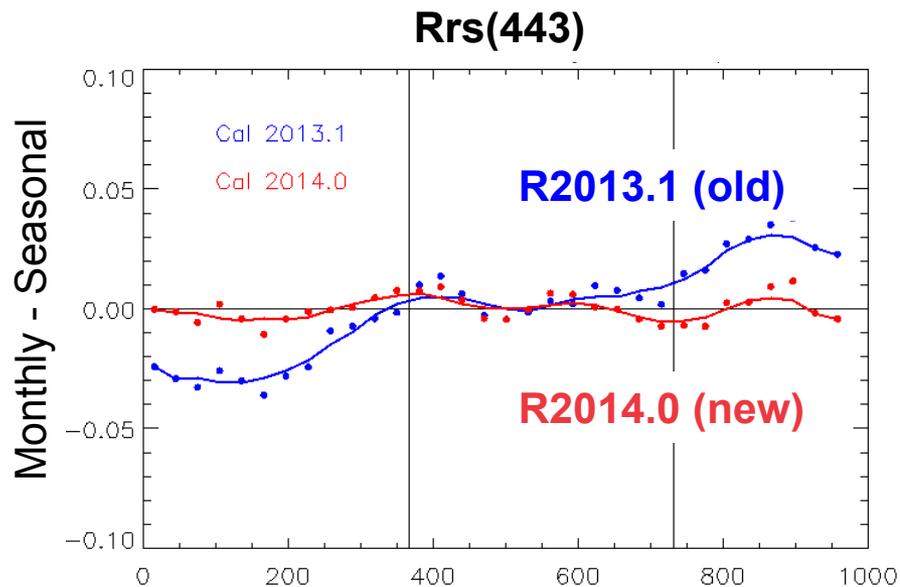
Reprocessing 2014.0



Calibration includes detector relative corrections
to reduce image striping artifacts.

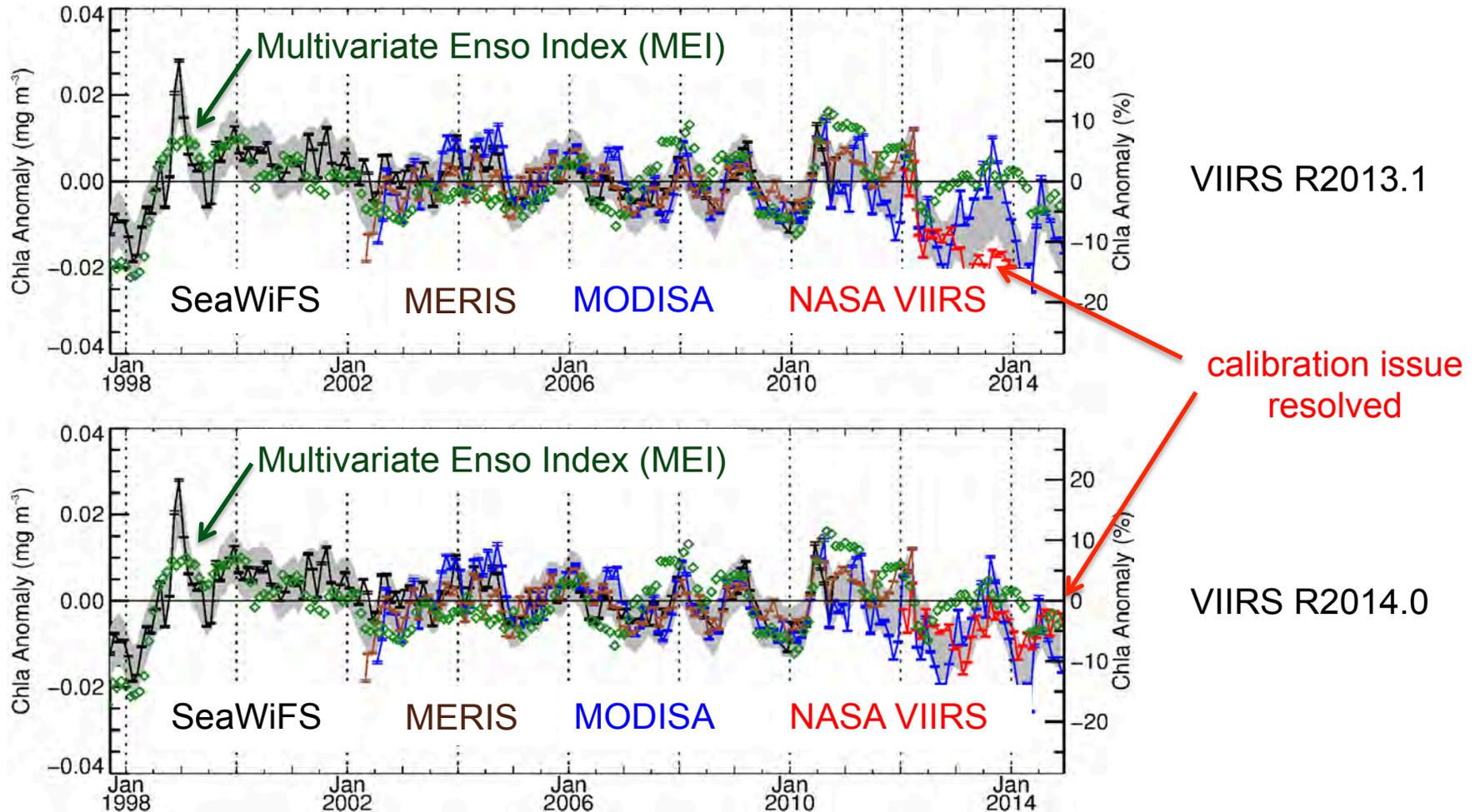
Improved VIIRS Ocean Product Temporal Stability

Global Mean Deep-Water Anomaly Trends



Global Mid-Latitude ($\pm 40^\circ$) Chlorophyll Anomaly

showing improved agreement of VIIRS with MODISA, MEI, and historical norms after R2014.0 reprocessing



Following Franz, B.A., D.A. Siegel, M.J. Behrenfeld, P.J. Werdell (2015). Global ocean phytoplankton [in State of the Climate in 2014]. Bulletin of the American Meteorological Society, submitted.

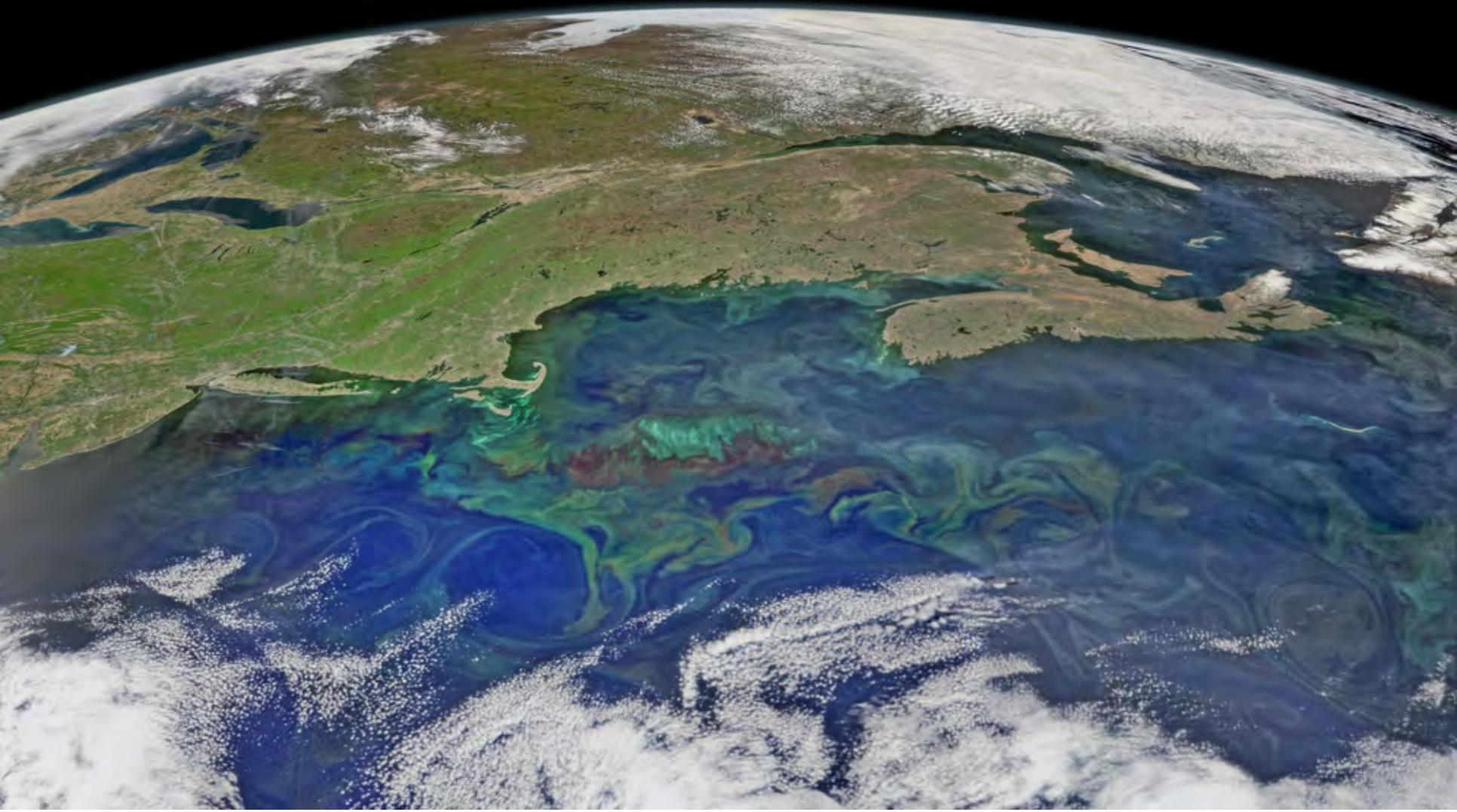
OBPG VIIRS On-Orbit Calibration Summary

- Significant elements of lunar calibration methodology include:
 - Use of modulated RSRs in ROLO model for lunar geometry corrections.
 - Application of empirical sub-spacecraft and sub-solar point libration corrections to VIIRS/ROLO model comparisons.
- Significant elements of solar calibration methodology include:
 - Use of detrended SDSM channel 8 time series to normalize H-factors.
 - Interpolation of H-factors to time basis of F-factors, allowing point-by-point correction of F-factors for diffuser BRDF degradation.
 - Derivation of absolute calibration of F-factors from the solar diffuser measurements, making SWIR bands useable for ocean color retrievals.
- Solar / lunar calibration comparisons results:
 - Slopes provide lunar-derived adjustments to the solar calibration time series and resulting F-factor LUTs.
 - VIIRS calibration stability comparable to that achieved for heritage instruments (SeaWiFS, Aqua MODIS).
- VIIRS ocean color data quality is sufficient for global trend studies.

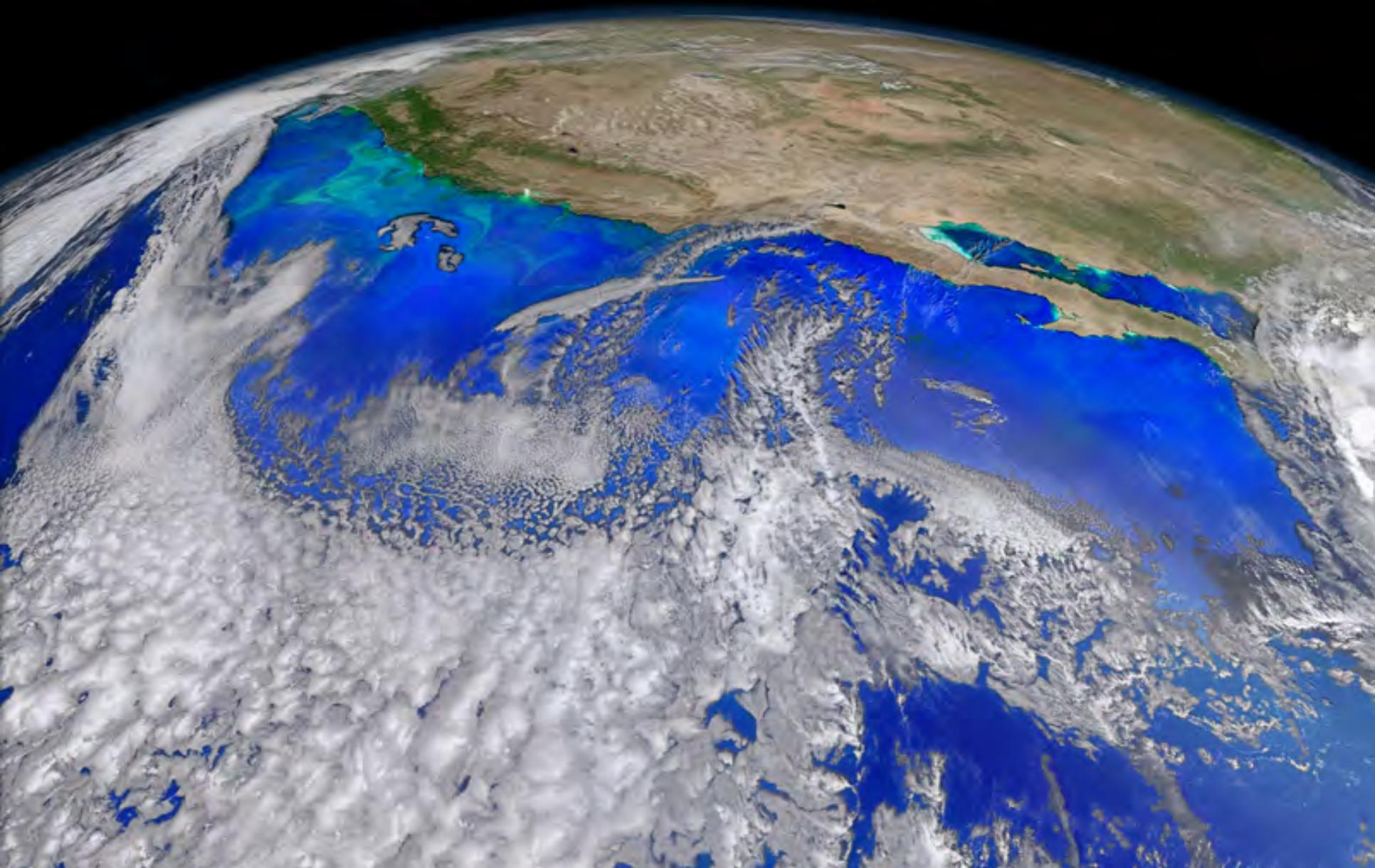
14 May 2015

Suomi-NPP / VIIRS

Thank You



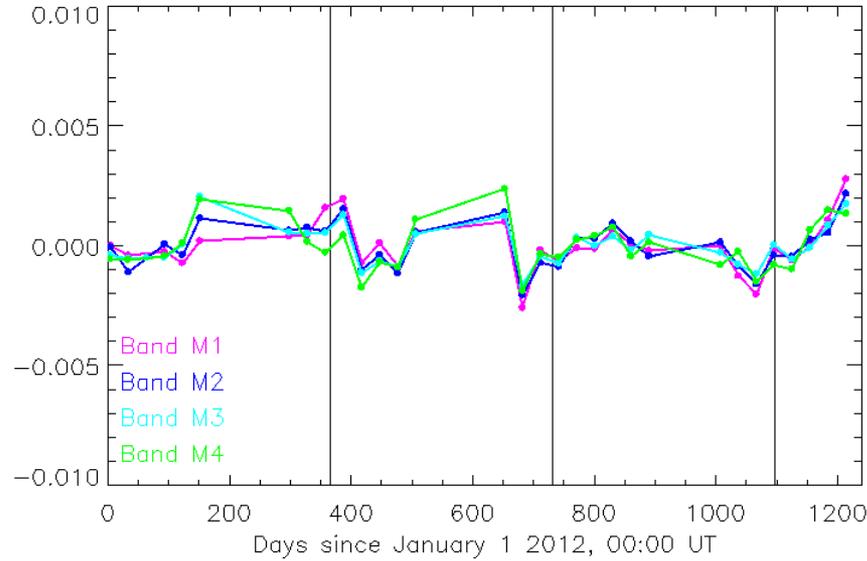
Thank You



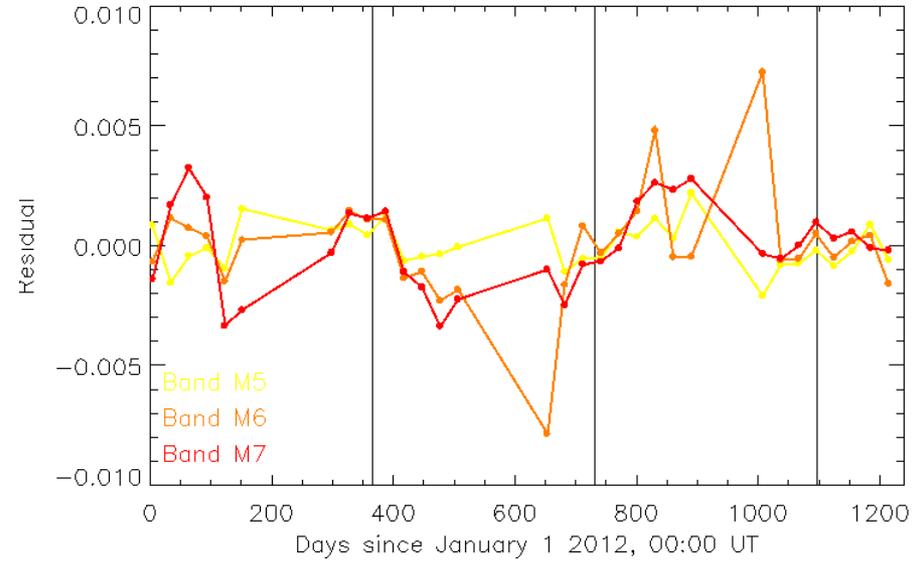
Backup Slides

Lunar Calibration Fit Residuals

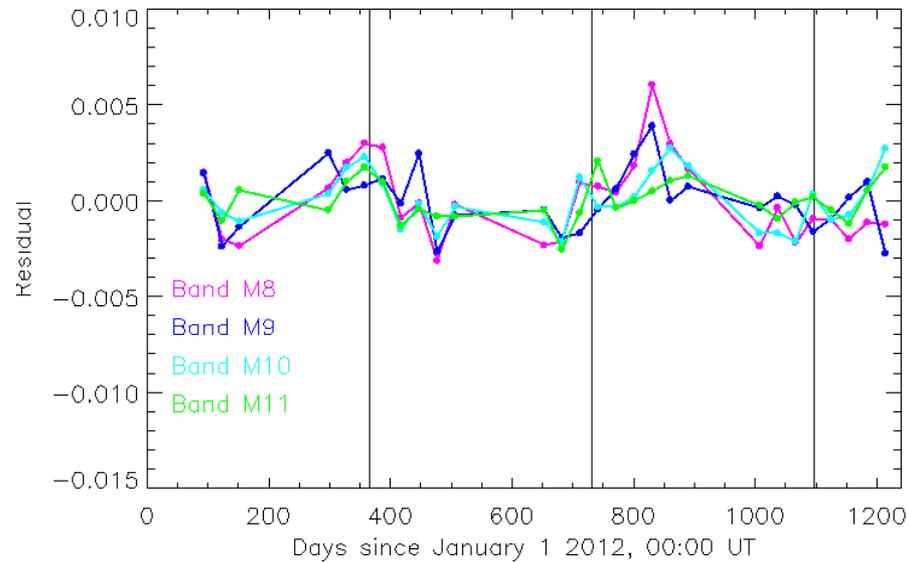
VIIRS VisNir Lunar Calibrations



VIIRS VisNir Lunar Calibrations



VIIRS SWIR Lunar Calibrations



Linear
Sub-Spacecraft
Libration Angle
Fits